ENCOAL® Mild Coal Gasification Project

Project completed

Participant

ENCOAL Corporation (a wholly owned subsidiary of Bluegrass Coal Development Company)

Additional Team Members

Bluegrass Coal Development Company (a wholly owned subsidiary of AEI Resources, Inc.)—cofunder

SGI International—technology developer, owner, licensor

Triton Coal Company (a wholly owned subsidiary of Vulcan Coal Company)— host

Location

Near Gillette, Campbell County, WY (Triton Coal Company's Buckskin Mine site)

Technology

SGI International's Liquids-From-Coal (LFC®) process

Coal

Low-sulfur Powder River Basin (PRB) subbituminous coal, 0.45% sulfur

Plant Capacity/Production

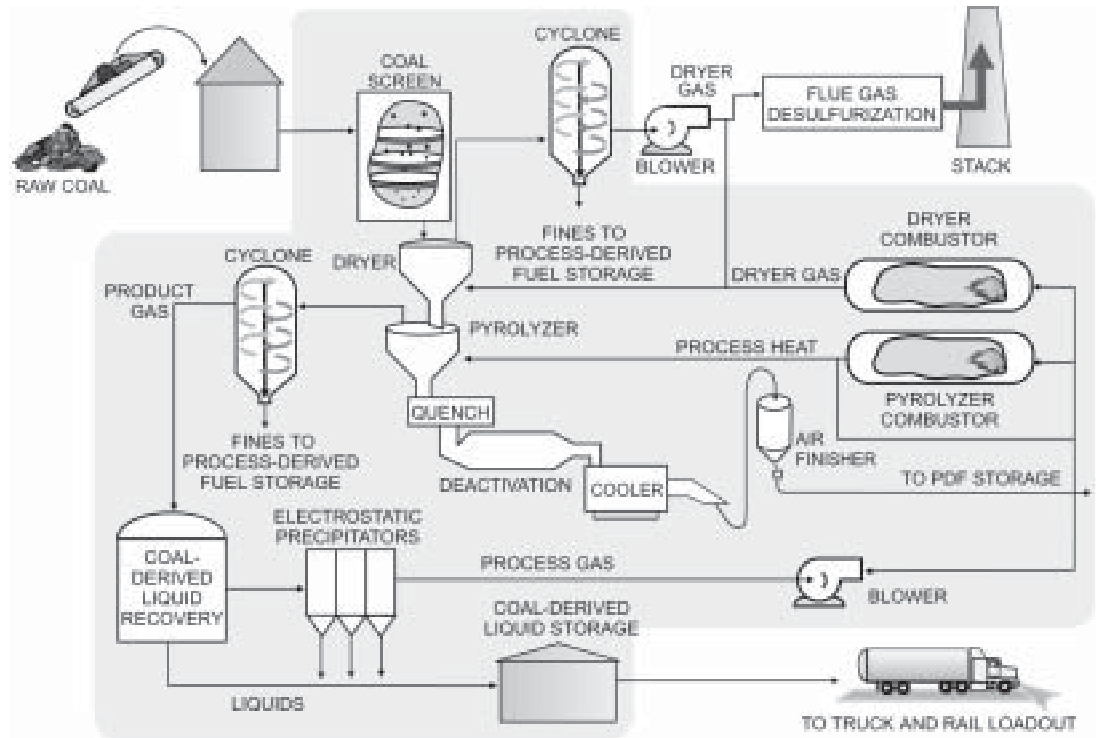
1,000 tons/day of subbituminous coal feed

Project Funding

Total project cost	$90,664,000	100%
DOE	45,332,000	50
Participant	45,332,000	50

Project Objective

To demonstrate the integrated operation of a number of novel processing steps to produce two higher-heating value fuel forms from mild gasification of low-sulfur subbituminous coal, and to provide sufficient products for potential end users to conduct burn tests.

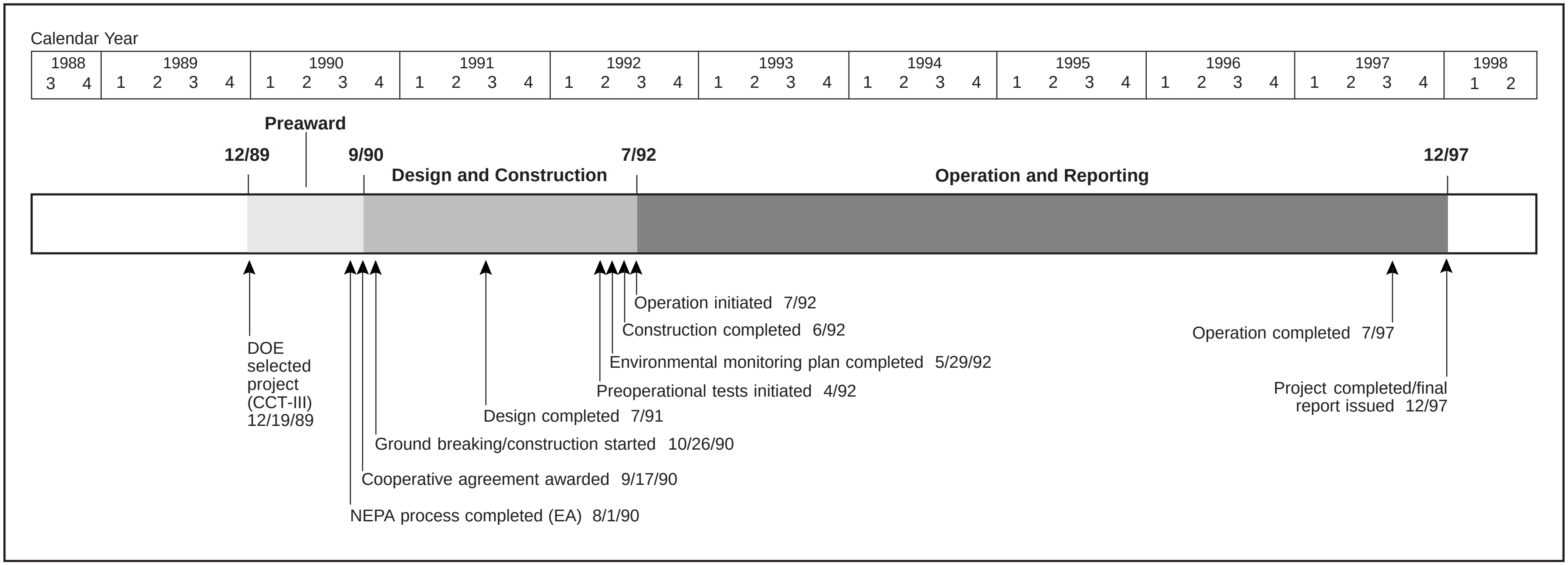


Technology/Project Description

Coal is fed into a rotary grate dryer where it is heated to reduce moisture. The temperature is controlled so that no significant amounts of methane, CO_2, or CO are released. The solids are then fed to the pyrolyzer where the temperature is about 1,000 °F, and all remaining water is removed. A chemical reaction releases the volatile gaseous material. Solids exiting the pyrolyzer are quenched to stop the pyrolysis reactions.

In the original process, the quench table solids were further cooled in a rotary cooler and transferred to a surge bin. A single 50% flow rate vibrating fluidized bed (VFB) was added to stabilize the Process-Derived Fuel (PDF®) with respect to oxygen and water. In the VFB, the partially cooled, pyrolyzed solids contact a gas stream containing a controlled amount of oxygen. Termed "oxidative deactivation," a reaction occurs at active surface sites on the particles, reducing the tendency for spontaneous ignition.

Following the VFB, the solids are cooled to near atmospheric temperature in an indirect rotary cooler where water is added to rehydrate the PDF®. A patented dust suppressant is added as the PDF® leaves the surge bin. The hot gas produced in the pyrolyzer is sent through a cyclone for removal of the particulates, and then cooled in a quench column to stop any additional pyrolysis reactions and to condense the Coal-Derived Liquid (CDL®).



Results Summary

Environmental

- The PDF® contains 0.36% sulfur with a heat content of 11,100 Btu/lb (compared with 0.45% sulfur and 8,300 Btu/lb for the feed coal).
- The CDL® contains 0.6% sulfur and 140,000 Btu/gal (compared with 0.8% sulfur and 150,000 Btu/gal for No. 6 fuel oil).
- In utility applications, PDF® enabled reduction in SO_2 emissions, reduction in NO_x emissions (through flame stabilization), and maintenance of boiler rated capacity with fewer mills in service.
- LFC® products contained no toxins in concentrations anywhere close to federal limits.

Operational

- Steady-state operation exceeding 90% availability was achieved for extended periods for the entire plant (numerous runs exceeded 120 days duration).
- The LFC® process consistently produced 250 tons/day of PDF® and 250 barrels/day of CDL® from 500 tons/day of run-of-mine PRB coal.
- Integrated operation of the LFC® process components over five years has provided a comprehensive database for evaluation and design of a commercial unit.
- Over 83,500 tons of PDF® were shipped via 17 unit trains and one truck shipment to seven customers in six states. Shipments included 100% PDF® and blends from 14–94% PDF®.
- PDF®, alone and in blends, demonstrated excellent combustion characteristics in utility applications, providing heating values comparable to bituminous coal, more reactivity than bituminous coal, and a stable flame.
- The low-volatile PDF® also showed promise as a reductant in direct iron reducing testing and also as a blast furnace injectant in place of coke.
- Nearly 5 million gallons of CDL® were produced and shipped to eight customers in seven states.
- CDL® demonstrated fuel properties similar to a low-sulfur No. 6 fuel oil but with the added benefit of lower sulfur content. High aromatic hydrocarbon content, however, may make CDL® more valuable as a chemical feedstock.

Economic

- A commercial plant designed to process 15,000 metric tons per day would cost an estimated $475 million (2001$) to construct, with annual operating and maintenance costs of $52 million per year.

Project Summary

Operational Performance

The LFC® facility operated for more than 15,000 hours over a five-year period. Steady-state operation was maintained for much of the demonstration with availabilities of 90% for extended periods. The length of operation and volume of production proved the soundness and durability of the process.

Exhibit 5-49 summarizes ENCOAL's production history. By the end of the demonstration, over 83,500 tons of PDF® were shipped via 17 unit trains and one truck shipment to seven customers in six states. Shipments included 100% PDF® and blends from 14–94% PDF®. Over 5 million gallons of CDL® were produced and shipped to eight customers in seven states.

As with most demonstrations, however, success required overcoming many challenges. The most difficult challenge was achieving stability of the PDF® product, which had to be resolved in order to achieve market acceptance.

In June 1993, efforts ceased in trying to correct persistent PDF® stability problems within the bounds of the original plant design. The rotary cooler failed to provide the deactivation necessary to quell spontaneous ignition of PDF®. ENCOAL concluded that a separate, sealed vessel was needed for product deactivation. A search for a suitable design led to adoption of a VFB. A 500-ton/day VFB was installed between the quench table and rotary cooler. (Plans were made for installation of a second 500 ton/day VFB but were never implemented.)

Although the VFB enhanced deactivation, the PDF still required "finishing" to achieve stabilization. Extensive study revealed that more oxygen was needed for deactivation. Two courses of action were pursued: (1) development of interim measures to finish deactivation external to the plant, enabling immediate PDF® shipment for test burns; and (2) development of an in-plant process for finishing, eliminating product quality and labor penalties for external finishing.

"Pile layering" was the primary external PDF® finishing measure adopted. However, PDF® quality becomes somewhat impaired due to changes in size, moisture, and ash content.

Pursuit of a finishing process step resulted in establishment of a stabilization task force composed of private sector and government engineers and scientists. The outcome was construction and testing of a Pilot Air Stabilization System (PASS) to complete the oxidative deactivation of PDF®. The PASS controls temperature and humidity during forced oxidation. The data obtained were used to develop specifications and design requirements for a full-scale, in-plant PDF® finishing unit based upon a commercial (Aeroglide) tower dryer design.

The first shipment of ENCOAL's liquid CDL® product experienced unloading problems. The use of heat tracing and tank heating coils solved the unloading problems for subsequent customers. The CDL® also contained more solids and water than had been hoped for, but was considered usable as a lower grade oil.

Following VFB installation, CDL® quality improved. The pour point ranged from 75–95 ºF, and the flash point averaged 230 ºF, both within the design range. Water content was down to 1–2%, and solids content was 2–4%. Improvements resulted from more consistent operation and lower pyrolysis temperatures and higher pyrolysis flow rates enabled by a new pyrolyzer water seal.

Environmental Performance

PDF® offers the advantages of low-sulfur Powder River Basin coal without a heating value penalty. In fact, the LFC® process removes organically bound sulfur, making the PDF® product lower in sulfur than the parent coal on a Btu basis. Because the ROM coal is low in ash, PDF® ash levels remain reasonable after processing, even though the ash level is essentially doubled (ash from one ton of ROM coal goes into one-half ton of PDF®).

Dust emissions were not a problem with PDF®. A dust suppressant (MK) was sprayed on the PDF® to coat the surface as it leaves the storage bin. Also, PDF® has a narrower particle size distribution than ROM coal, having a larger fines content but fewer particles in the fugitive dust range than ROM coal.

ENCOAL's test burn shipments became international when Japan's Electric Power Development Company (EPDC) evaluated six metric tons of PDF® in 1994. The EPDC, which must approve all fuels being considered for electric power generation in Japan, found PDF® acceptable for use in Japanese utility boilers.

In October 1996, instrumented combustion testing was conducted at the Indiana-Kentucky Electric Co-

Exhibit 5-49
ENCOAL Production

	Pre-VFB 1992	1993	Post-VFB 1994	1995	1996	1997[1]	Total
Raw Coal Feed (tons)	5,200	12,400	67,500	65,800	68,000	39,340	**258,300**
PDF® Produced (tons)	2,200	4,900	31,700	28,600	33,300	19,300	**120,500**
PDF® Sold (tons)	0	0	23,700	19,100	32,700	7,400	**82,900**
CDL® Produced (bbl)	2,600	6,600	28,000	31,700	32,500	20,300	**121,700**
Hours on Line	314	980	4,300	3,400	3,600	2,603	**15,197**
Average Length of Runs (Days)	2	8	26	38	44	75	**N/A**

[1]Through June 1997.

operative's (IKEC) Clifty Creek Station, Unit No. 3. Important findings included the following:

- Full generating capacity using PDF® was possible with one mill out of service, which was not possible using the baseline fuel. Operation using PDF® afforded time to perform mill maintenance and calibration without losing capacity or revenues, increasing capacity factor and availability, and decreasing operation and maintenance costs.
- NO_x emissions were reduced by 20% due to high PDF® reactivity, resulting in almost immediate ignition upon leaving the burner coal nozzle. Furthermore, PDF® sustained effective combustion (maintaining low loss on ignition) with very low excess oxygen, which is conducive to low NO_x emissions.
- PDF® use precipitated increased ash deposits in the convective pass that were wetter than those resulting from baseline coal use, requiring increased sootblowing to control build-up.

The CDL® liquid product is a low-sulfur, highly aromatic, heavy liquid hydrocarbon. CDL® fuel characteristics are similar to those of a low-sulfur No. 6 fuel oil, except that the sulfur content is significantly lower. CDL®'s market potential as a straight industrial residual fuel, however, appears limited. The market for CDL® as a fuel never materialized, and CDL® has limited application as a blend for high-sulfur residual fuels due to incompatibility of the aromatic CDL® with many straight-chain hydrocarbon distillates.

ENCOAL determined that a centrifuge was needed to reduce solids retention and improve marketability of CDL® (tests validated a 90% removal capability); and an optimum slate of upgraded products was identified. The upgraded products were: (1) crude cresylic acid, (2) pitch, (3) refinery feedstock (low-oxygen middle distillate), and (4) oxygenated middle distillate (industrial fuel).

Economic

The "base case" for economics of a commercial plant is the 15,000-metric-ton/day, three-unit North Rochelle LFC® plant, the commercial-scale plant proposed by ENCOAL, with an independent 80-MWe cogeneration unit, and no synthetic fuel tax credit (29c tax credit). It is assumed that the cogeneration unit is owned and operated by an independent third party. The capital cost for a full-scale, three-module LFC® plant is $475 million.

Economic benefits from an LFC® commercial plant are derived from the margin in value between a raw, unprocessed coal and the upgraded products, making an LFC® plant dependent on the cost of feed coal. In fact, this is the largest single operating cost item. The total estimated operating cost is $9.00/ton of feed coal including the cost of feed coal, chemical supplies, maintenance, and labor.

Commercial Applications

In a commercial application, CDL® would be upgraded to cresylic acid, pitch, refinery feedstock, and oxygenated middle distillate. Oxygenated middle distillate, the lowest value by-product, would be used in lieu of natural gas as a make-up fuel for the process (30% of the process heat input). PDF® would be marketed not only as a boiler fuel but as a supplement to or substitute for coke in the steel industry. PDF® characteristics make it attractive to the metallurgical market as a coke supplement in pulverized-coal-injection and granular-coal-injection methods, and as a reductant in direct reduced iron processes.

Partners in the ENCOAL® project completed five detailed commercial feasibility studies over the course of the demonstration and shortly thereafter—two Indonesian, one Russian, and two U.S. projects. A U.S. project has received an Industrial Siting Permit and an Air Quality Construction Permit, but the project is on hold due to lack of funding.

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